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Editorial

Advances in glass and glass crystalline materials: An overview

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Abstract: Investigation of glasses and glass crystalline composite materials occupies a special place in modern science. Their use in new materials enables innovative and breakthrough technologies in industry, electronics, and other areas of human activity. Understanding the nature of glass and the properties of glass-based materials is a key task in fundamental science, presenting great value for different applications, including glass processing, development of flexible glasses, and concrete reinforcement. The research presented in this special issue, focusing on new glass-based materials and relaxation processes in condensed matter, is interdisciplinary and has great practical significance.

Keywords: glass; glass crystalline composites; functional glasses; composite materials; fibre reinforcement; recycling & sustainability; mechanical properties; interfacial phenomena; smart materials

1. Introduction

While the physics of crystalline solids benefits from well-established theories and research methods, the study of vitreous solids still lacks a unified theory, and common methods and approaches prove ineffective. Nevertheless, certain aspects of the behaviour of glassy materials, such as relaxation processes, have been described quite successfully in numerous studies [1–6]. Various modelling approaches applicable to vitreous systems have also shown promising results. For example, using data on the temperature dependence of the viscosity of glass-forming melts, a recent study [7] proposed an estimate of the activation energy of viscous flow for chalcogenide glasses using the Williams–Landel–Ferry equation, thereby contributing to the study of relaxation processes in glasses. Based on this approach, investigations of the kinetic aspects of glass transition in two-component chalcogenide, lead, and borate glasses [8,9] have enabled quantitative determination of key parameters of the liquid–glass transition, such as the glass transition temperature range and the structural relaxation time, thus deepening the understanding of relaxation processes in amorphous materials.

One of the most pressing challenges in materials science is the discovery and development of new functional materials with tailored properties that drive advances in critical areas of science and technology. In this context, glass and glass-based composites occupy a special place among functional materials. They exhibit a number of unique advantages, such as isotropy, homogeneity, viscous flow behaviour, wide component concentration variations, and absence of porosity. These properties allow glass to acquire desired functional properties without significantly compromising its other advantages, making it extremely attractive for the development of new functional materials.

Extensive experimental data on the structure-sensitive properties of glass has now been accumulated, and new glass-based composites, functional and smart glasses, and methods for using and processing glassy materials continue to be developed. To introduce scientific advances in this field, a brief summary of the articles selected for this special issue is provided below. The publications cover a wide range of interdisciplinary topics and are of particular value to the scientific community.

2. An overview of this Special Issue

Within this Special Issue, the study by Haryanti et al. [10] investigates hybrid composites based on a polyester matrix reinforced with long *Eleocharis dulcis* fibres and E-glass, modified by NaOH and hot water treatment. The research demonstrates that both alkaline and thermal treatments enhance the physical and mechanical properties of natural fibres, with an optimal hybrid ratio of natural to synthetic fibres (sample D) yielding high tensile strength. This work contributes to the development of sustainable composite materials using natural fibres, complementing the broader scope of the issue on advances in glass and glass-crystalline materials with insights into biodegradable and hybrid reinforcement systems.

The work by Chimytov et al. [11] explores memory effects in polymer-dispersed liquid crystal (PDLC) composites formed from 4-cyano-4'-pentylbiphenyl (5CB) and polyvinyl acetate (PVAc) via solvent-induced phase separation. The study reveals that a significant and conditionally irreversible capacitance memory (M = 0.17) emerges specifically in the 5CB/PVAc = 2/1 composition, which exhibits a complex morphology with non-spherical droplets and topological defects (+1 disclinations), while the 1/1 ratio shows no memory. This contribution provides valuable insights into the design of electrically programmable, non-volatile optical memory devices based on LC-polymer systems, aligning with the special issue's theme on advanced functional glass and glass-crystalline materials by introducing a tunable, soft-matter approach to state retention and electro-optical control.

The article by Cheng [12] revisits the long-standing problem of helium permeation through silica glass, which is six orders of magnitude higher than through crystalline quartz despite their identical chemical composition. It critiques the traditional continuous random network (CRN) theory and instead employs a recently proposed nanoflake structural model to explain the phenomenon. The model posits that the formation of one-dimensional, medium-range ordered nanoflakes during glass cooling creates nanoscale fissures held by weak van der Waals bonds, which serve as preferential diffusion channels for small helium atoms, thereby providing a coherent structural origin for the exceptional permeability and related mechanical properties of vitreous silica.

The study by Shiverskii et al. [13] addresses the critical issue of recycling glass fibre-reinforced plastic (GFRP) waste by investigating its use as a partial replacement for gravel in asphalt concrete. Utilizing crumb from shredded GFRP noise barriers, the research demonstrates that incorporating 2% GFRP crumb significantly enhances key mechanical properties, most notably increasing the compressive modulus by 40% even at elevated service temperatures of 50 °C, thereby improving rutting resistance. This approach not only provides a practical and scalable solution for diverting thermoset GFRP waste from landfills but also contributes to sustainability purposes by reducing the overall weight of the pavement mixture, showcasing a successful path toward circular economy principles in construction materials.

The article by Yu et al. [14] systematically investigates the impact of waste glass powder (WGP) particle size and replacement content on the bond-slip performance of reinforced concrete. The experimental results reveal that a 10% replacement content with a fine particle size (<20 µm) yields optimal improvement, enhancing bond strength by 5.3% and reducing peak slip by 18.3%–30%, primarily due to the enhanced pozzolanic reaction and pore-filling effect that densify the interfacial transition zone. Conversely, larger particle sizes (>75 µm) or higher replacement levels (30%) lead to reduced bond strength, increased slip, and a shift in failure mode from ductile pull-out to brittle splitting, attributed to the promotion of deleterious alkali-silica reactions. The study culminates in the development of a refined bond-slip constitutive model that successfully captures the synergistic effects of particle size and content, providing a valuable theoretical framework for the sustainable utilization of waste glass in concrete engineering.

The article by Langgemach et al. [15] investigates the mechanical reliability of ultra-thin flexible glass (UTG) under cyclic loading, a critical factor for its application in flexible electronics. The study finds that cyclic loading significantly reduces UTG strength compared to quasi-static conditions, a decrease primarily driven by moisture-assisted cyclic crack growth. Key results show that amorphous thin film coatings (as-deposited ITO and antireflective stacks) can mitigate this fatigue effect, likely by providing a barrier against humidity, while crystalline (annealed) ITO coatings lead to a pronounced strength reduction under all loading conditions. The research provides essential insights for optimizing coating processes and cutting techniques to enhance the production reliability of advanced glass-based components.

3. Conclusions

This special issue displays an interdisciplinary approach to glass and glass-ceramic materials research. The research articles combine fundamental research with applied innovations in composite materials and waste recycling. The papers offer practical solutions for creating more environmentally friendly and high-performance materials for flexible electronics, construction, and other applications.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

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Conflict of interest

Michael I. Ojovan, Migmar V. Darmaev and Alexey A. Mashanov are on a special issue editorial board for *AIMS Materials Science* and were not involved in the editorial review or the decision to publish this article. All authors declare that there are no competing interests.

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